

APPENDIX B
POWER ANALYSIS

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Power Analysis

The program TRENDS was used to calculate the power to detect a trend over the monitoring period. TRENDS was obtained at the following address on the web site of the Southwest Fisheries Science Center of the National Marine Fisheries Service of the National Oceanic and Atmospheric Administration: <http://swfsc.nmfs.noaa.gov/prd/software/Trends.html>.

The power analysis in this program is based on a simple linear regression. The TRENDS program is summarized in 6 parameters: duration of study, sampling frequency, rate of change, measurement variability, alpha (type 1 error rate), and power (1-beta, where beta is the type 2 error rate). The TRENDS program estimates any one of the parameters if the other 5 are specified.

Power analysis tables were constructed using the TRENDS program. The tables report the statistical power for detecting a linear trend over a range of parameters that cover realistically expected ranges of sampling periods, sampling frequencies, alpha levels, rates of change, and measurement variability (coefficient of variation) at ED-1. The ranges chosen were: a 5-year (Tables 1 through 12) and 10-year sampling period (Tables 13 through 24); alpha levels of 0.05 (Tables 1 to 4 and 13-16), 0.10 (Tables 5 to 8 and 17-20), and 0.15 (Tables 9 to 12 and 21-24); and coefficients of variation of 20% (Tables 1, 5, 9, 13, 17, and 21), 40% (Tables 2, 6, 10, 14, 18, and 22), 60% (Tables 3, 7, 11, 15, 19, and 23), and 120% (Tables 4, 8, 12, 16, 20, and 24). The rows of each table show the power for a different sampling frequency from once-every-other-year to 4 samples per year. The columns of each table show a hypothetical rate of change per year from -20% to +5%.

To determine the power to detect a trend, find the variability of the measurement of interest by selecting the coefficient of variation (CV) from the summary statistics and select the monitoring period of interest. Then look at the power table for that CV and monitoring period. Look at Table 13 if the CV is 20% and the monitoring period 10 years. The table shows that if sampling is conducted once per year and the desired confidence is $P = 0.95$ (alpha = 0.05), the power to detect a decrease of 5% per year is 0.76. That means that there is a 76% chance that the trend would be detected.

These power analysis tables can be used prior to sampling to estimate the number of samples needed to achieve a desired power. They can be used after sampling to estimate the power achieved by the sampling effort given the actual CV of the data and the observed percentage difference of means.

References

<http://swfsc.nmfs.noaa.gov/prd/software/Trends.html>

Gerrodette, T. 1987. A Power analysis for detecting trends. Ecology 68: 1364-1372

Gerrodette, T. 1991. Models for power of detecting trends – a reply to Link and Hatfield. Ecology 72: 1889-1892.

Gerrodette, T. 1993. Trends: Software for a power analysis of linear regression. Wildlife Society Bulletin 21: 515-516

Table 1. Power to Detect Change Using Linear Regression Over a 5-Year Sampling Period at an Alpha Level of 0.05 and 20% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.43	0.2	0.13	0.12	0.12	0.13
1 Sample/year	0.92	0.39	0.16	0.11	0.1	0.15
2 Samples/year	1	0.62	0.24	0.14	0.13	0.21
4 Samples/year	1	0.85	0.35	0.18	0.17	0.31

Table 2. Power to Detect Change Using Linear Regression Over a 5-Year Sampling Period at an Alpha Level of 0.05 and 40% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.23	0.13	0.11	0.11	0.11	0.11
1 Sample/year	0.47	0.17	0.1	0.08	0.08	0.09
2 Samples/year	0.73	0.25	0.12	0.09	0.08	0.11
4 Samples/year	0.93	0.38	0.16	0.1	0.1	0.14

Table 3. Power to Detect Change Using Linear Regression Over a 5-Year Sampling Period at an Alpha Level of 0.05 and 60% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.17	0.12	0.11	0.11	0.11	0.11
1 Sample/year	0.28	0.12	0.08	0.07	0.07	0.08
2 Samples/year	0.44	0.16	0.09	0.07	0.07	0.09
4 Samples/year	0.67	0.23	0.11	0.08	0.08	0.1

Table 4. Power to Detect Change Using Linear Regression Over a 5-Year Sampling Period at an Alpha Level of 0.05 and 120% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.12	0.11	0.11	0.11	0.11	0.11
1 Sample/year	0.14	0.08	0.07	0.06	0.06	0.07
2 Samples/year	0.19	0.09	0.07	0.06	0.06	0.07
4 Samples/year	0.27	0.12	0.08	0.06	0.06	0.07

Table 5. Power to Detect Change Using Linear Regression Over a 5-Year Sampling Period at an Alpha Level of 0.10 and 20% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.74	0.38	0.24	0.2	0.19	0.23
1 Sample/year	0.98	0.59	0.29	0.2	0.19	0.27
2 Samples/year	1	0.77	0.37	0.24	0.23	0.34
4 Samples/year	1	0.93	0.5	0.3	0.29	0.46

Table 6. Power to Detect Change Using Linear Regression Over a 5-Year Sampling Period at an Alpha Level of 0.1 and 40% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.43	0.24	0.19	0.18	0.18	0.19
1 Sample/year	0.68	0.3	0.18	0.15	0.14	0.17
2 Samples/year	0.86	0.4	0.21	0.16	0.16	0.2
4 Samples/year	0.97	0.54	0.26	0.18	0.18	0.24

Table 7. Power to Detect Change Using Linear Regression Over a 5-Year Sampling Period at an Alpha Level of 0.1 and 60% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.32	0.21	0.18	0.17	0.17	0.18
1 Sample/year	0.46	0.22	0.15	0.13	0.13	0.15
2 Samples/year	0.61	0.27	0.17	0.14	0.14	0.16
4 Samples/year	0.8	0.36	0.2	0.15	0.15	0.19

Table 8. Power to Detect Change Using Linear Regression Over a 5-Year Sampling Period at an Alpha Level of 0.1 and 120% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.22	0.18	0.17	0.17	0.17	0.17
1 Sample/year	0.25	0.16	0.13	0.12	0.12	0.13
2 Samples/year	0.31	0.17	0.13	0.12	0.12	0.13
4 Samples/year	0.41	0.21	0.14	0.12	0.12	0.14

Table 9. Power to Detect Change Using Linear Regression Over a 5-Year Sampling Period at an Alpha Level of 0.15 and 20% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.9	0.54	0.34	0.28	0.27	0.32
1 Sample/year	1	0.71	0.39	0.28	0.27	0.36
2 Samples/year	1	0.85	0.48	0.32	0.31	0.44
4 Samples/year	1	0.96	0.61	0.39	0.38	0.56

Table 10. Power to Detect Change Using Linear Regression Over a 5-Year Sampling Period at an Alpha Level of 0.15 and 40% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.6	0.35	0.26	0.24	0.24	0.26
1 Sample/year	0.79	0.41	0.26	0.21	0.21	0.25
2 Samples/year	0.91	0.5	0.29	0.23	0.22	0.28
4 Samples/year	0.98	0.64	0.35	0.26	0.25	0.33

Table 11. Power to Detect Change Using Linear Regression Over a 5-Year Sampling Period at an Alpha Level of 0.15 and 60% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.45	0.29	0.24	0.23	0.23	0.24
1 Sample/year	0.58	0.31	0.22	0.19	0.19	0.21
2 Samples/year	0.71	0.37	0.24	0.2	0.2	0.23
4 Samples/year	0.86	0.46	0.27	0.22	0.21	0.26

Table 12. Power to Detect Change Using Linear Regression Over a 5-Year Sampling Period at an Alpha Level of 0.15 and 120% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.31	0.25	0.23	0.22	0.22	0.23
1 Sample/year	0.34	0.23	0.19	0.17	0.17	0.18
2 Samples/year	0.41	0.25	0.19	0.17	0.17	0.19
4 Samples/year	0.51	0.28	0.21	0.18	0.18	0.2

Table 13. Power to Detect Change Using Linear Regression Over a 10-Year Sampling Period at an Alpha Level of 0.05 and 20% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	1	0.92	0.39	0.2	0.18	0.3
1 Sample/year	1	1	0.76	0.38	0.32	0.59
2 Samples/year	1	1	0.95	0.58	0.49	0.83
4 Samples/year	1	1	1	0.82	0.72	0.97

Table 14. Power to Detect Change Using Linear Regression Over a 10-Year Sampling Period at an Alpha Level of 0.05 and 40% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.96	0.47	0.17	0.11	0.1	0.14
1 Sample/year	1	0.87	0.32	0.17	0.15	0.24
2 Samples/year	1	0.99	0.49	0.24	0.2	0.36
4 Samples/year	1	1	0.73	0.36	0.3	0.56

Table 15. Power to Detect Change Using Linear Regression Over a 10-Year Sampling Period at an Alpha Level of 0.05 and 60% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.75	0.28	0.12	0.09	0.08	0.11
1 Sample/year	1	0.59	0.2	0.12	0.11	0.15
2 Samples/year	1	0.82	0.29	0.15	0.13	0.22
4 Samples/year	1	0.97	0.45	0.22	0.18	0.33

Table 16. Power to Detect Change Using Linear Regression Over a 10-Year Sampling Period at an Alpha Level of 0.05 and 120% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.33	0.14	0.08	0.07	0.07	0.08
1 Sample/year	0.81	0.24	0.11	0.08	0.07	0.09
2 Samples/year	0.97	0.36	0.14	0.09	0.08	0.11
4 Samples/year	1	0.56	0.19	0.11	0.1	0.15

Table 17. Power to Detect Change Using Linear Regression Over a 10-Year Sampling Period at an Alpha Level of 0.1 and 20% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	1	0.98	0.59	0.34	0.31	0.48
1 Sample/year	1	1	0.88	0.54	0.47	0.75
2 Samples/year	1	1	0.98	0.72	0.64	0.91
4 Samples/year	1	1	1	0.9	0.84	1

Table 18. Power to Detect Change Using Linear Regression Over a 10-Year Sampling Period at an Alpha Level of 0.1 and 40% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	1	0.6	0.3	0.2	0.19	0.26
1 Sample/year	1	0.98	0.48	0.28	0.25	0.38
2 Samples/year	1	1	0.65	0.37	0.32	0.51
4 Samples/year	1	1	0.84	0.5	0.44	0.7

Table 19. Power to Detect Change Using Linear Regression Over a 10-Year Sampling Period at an Alpha Level of 0.1 and 60% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.9	0.46	0.22	0.17	0.16	0.2
1 Sample/year	1	0.74	0.32	0.21	0.19	0.26
2 Samples/year	1	0.91	0.43	0.26	0.23	0.34
4 Samples/year	1	0.99	0.59	0.34	0.3	0.47

Table 20. Power to Detect Change Using Linear Regression Over a 10-Year Sampling Period at an Alpha Level of 0.1 and 120% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.51	0.25	0.16	0.13	0.13	0.15
1 Sample/year	0.7	0.31	0.17	0.14	0.13	0.16
2 Samples/year	0.88	0.41	0.21	0.15	0.15	0.18
4 Samples/year	0.98	0.57	0.26	0.18	0.17	0.22

Table 21. Power to Detect Change Using Linear Regression Over a 10-Year Sampling Period at an Alpha Level of 0.15 and 20% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	1	1	0.71	0.45	0.41	0.61
1 Sample/year	1	1	0.93	0.65	0.58	0.83
2 Samples/year	1	1	0.99	0.8	0.73	0.95
4 Samples/year	1	1	1	0.94	0.89	1

Table 22. Power to Detect Change Using Linear Regression Over a 10-Year Sampling Period at an Alpha Level of 0.15 and 40%a CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	1	0.79	0.41	0.29	0.27	0.35
1 Sample/year	1	0.97	0.58	0.37	0.34	0.48
2 Samples/year	1	1	0.74	0.46	0.42	0.61
4 Samples/year	1	1	0.89	0.6	0.54	0.78

Table 23. Power to Detect Change Using Linear Regression Over a 10-Year Sampling Period at an Alpha Level of 0.15 and 60% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.96	0.58	0.31	0.24	0.23	0.28
1 Sample/year	1	0.82	0.42	0.29	0.27	0.35
2 Samples/year	1	0.95	0.53	0.34	0.31	0.44
4 Samples/year	1	1	0.69	0.43	0.39	0.57

Table 24. Power to Detect Change Using Linear Regression Over a 10-Year Sampling Period at an Alpha Level of 0.15 and 120% CV.

Sampling Frequency	Change Per Year					
	-20%	-10%	-5%	-3%	+3%	+5%
1 Sample every other year	0.64	0.34	0.23	0.19	0.19	0.21
1 Sample/year	0.79	0.41	0.25	0.2	0.2	0.23
2 Samples/year	0.93	0.51	0.28	0.22	0.21	0.25
4 Samples/year	1	0.66	0.34	0.25	0.24	0.3

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